University Physics

Principles of Physics (12th Edition)

Halliday, Resnick, Walker

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Self-introduction

2000–2010　南京大学物理系（本科—博士）

2008–2010　Lawrence Berkeley国家实验室

（联合培养）

2010–2012　清华大学工程物理系（博士后）

UCLA, Brookhaven国家实验室访问学者

2012–2017　澳門科技大學太空科學研究所助理教授

2017–2023　澳門科技大學太空科學研究所副教授

2023–　　澳門科技大學太空科學研究所教授

注意事项（important）

- 缺課大於30%，取消考試資格
  （三次遲到 /早退 = 一次曠課）
- 保持課堂安靜
- 不懂隨時提問
- 積極參與課堂討論

物理1-2509微信群

群聊：物理1-2509

该二维码7天内(9月8日前)有效，重新进入将更新

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Evaluation:

Final Exam — 50%

Final Report — 25%

Homework — 10%

Classwork— 15%　(課堂参与，包括课堂练习，回答問題，師生互動等)

曠課超過10%，扣除學期總分3分

曠課超過15%，扣除學期總分8分

怎樣學好物理?

- ✓ 按時上課
- ✓ 学好英文物理名词
- ✓ 認真看書
- ✓ 複習課件，研究例題
- ✓ 認真完成作業，多做練習
- ✓ 多思考日常現象的物理原理
- ✗ 不上課
- ✗ 抄襲作業
- ✗ 不複習
- ✗ 考試臨時抱佛腳
- ✗ 知識、概念似是而非

What is Physics ?

物理：萬物之理；道（法自然）；易經
（Universal law of variation）

Physics is the discipline of science most directly concerned with the fundamental law of nature
（研究自然界的基本规律）.

Physics deals with basic components of matter, motion and their interactions（研究物质，运动及其相互作用）.

Why Physics ?

Physics answers the ultimate question of human:
what is the origin of our universe? (宇宙起源)

《天問》－屈原
(約公元前351－前278)

《天問》

曰遂古之初，谁传道之？
上下未形，何由考之？
冥昭瞢闇，谁能极之？
冯翼惟像，何以识之？
明明闇闇，惟时何为？
阴阳三合，何本何化？
圜则九重，孰营度之？
惟兹何功，孰初作之？
斡维焉系，天极焉加？
八柱何当，东南何亏？
九天之际，安放安属？
隅隈多有，谁知其数？
天何所沓？十二焉分？
日月安属？列星安陈？

请问：关于远古的开头，谁个能够传授？
那时天地未分，能根据什么来考究？
那时浑浑沌沌，谁个能够弄清？
有什么在回旋浮动，如何可以分明？

无底的黑暗生出光明，这样为的何故？
阴阳二气，渗合而生，它们的来历又在何处？
穹庐的天盖共有九层，是谁动手经营？
这样一个工程何等伟大，谁个是最初的工人？

这天盖的伞把子，到底插在什么地方？
绳子，究竟拴在何处，来扯着这个逢帐？
八方有八根擎天柱，指的毕竟是什么山？
东南方是海水所在，擎天柱岂不会完蛋？

九重天盖的边缘，是放在什么东西上面？
既有很多弯曲，谁个把它的度数晓得周全？
到底根据什么尺子，把天体分成了十二等分？
太阳和月亮何以不坠？星宿何以嵌得很稳？

《天對》--- 柳宗元（773年 – 819年）

问曰：遂古之初，谁传道之？上下未形，何由考之？冥昭瞢暗，谁能极之？冯翼惟像，何以识之？明明暗暗，惟时何为？

对曰：本始之茫，诞老者传焉。鸿灵幽纷，曷可言焉！黑晰眇，往来屯屯，庞昧革化，惟元气存，而何为焉！

阴阳三合，何本何化？

合焉者三，一以统同。吁炎吹冷，交错而功。

圜则九重，孰营度之？

无营以成，沓阳而九。运辕浑沦，蒙以圜号。

惟兹何功，孰初作之？

冥凝元，无功无作。

斡维焉系？天极焉加？

乌溪系维，乃糜身位。无极之极，溾亻非垠。或形之加，孰取大焉！

八柱何当，东南何亏？

皇熙，胡栋胡宇！宏离不属，焉恃夫八柱！

九天之际，安放安属？

无青无黄，无赤无黑。无中无旁，乌际乎天则。

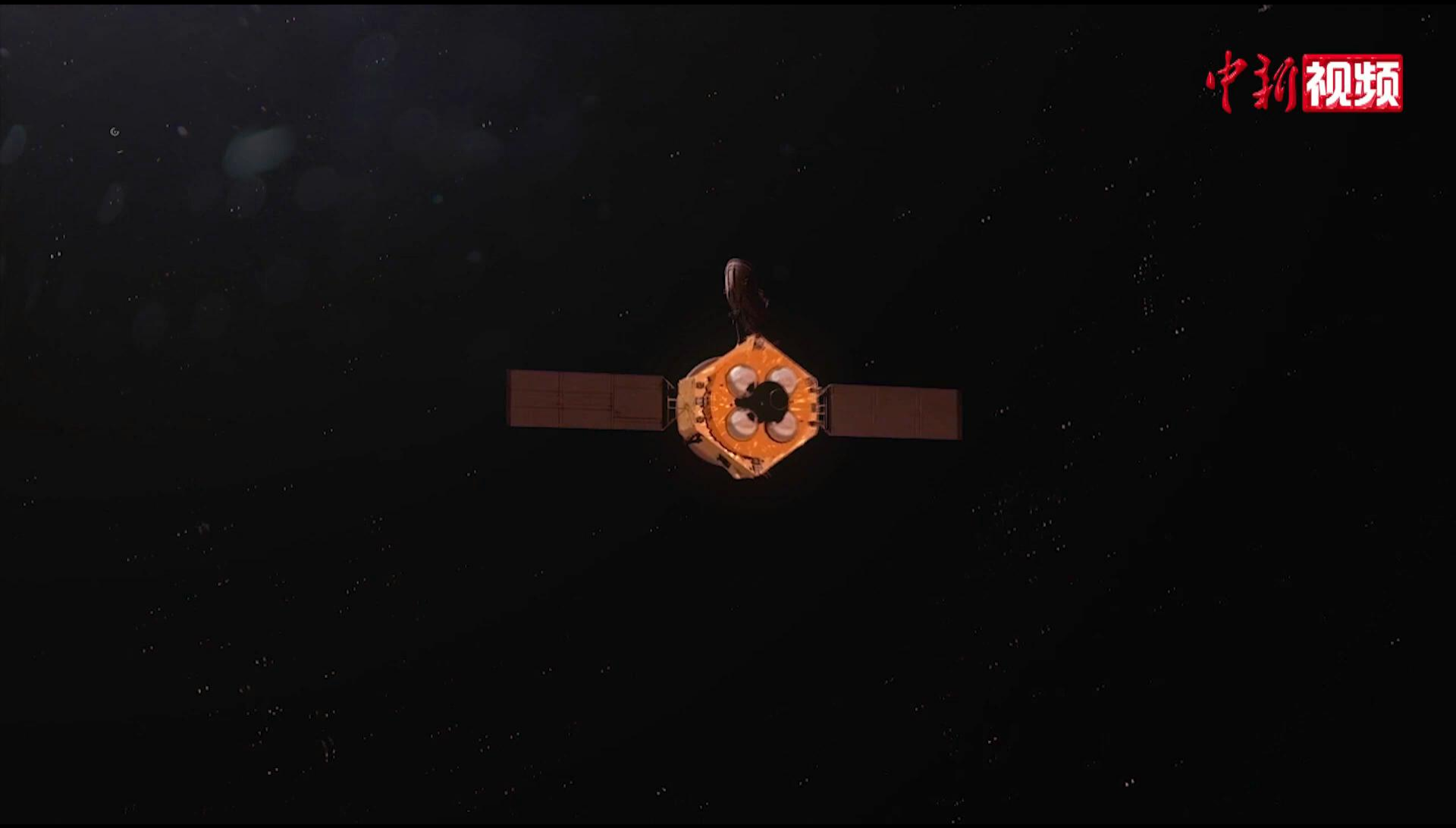
隅隈多有，谁知其数？

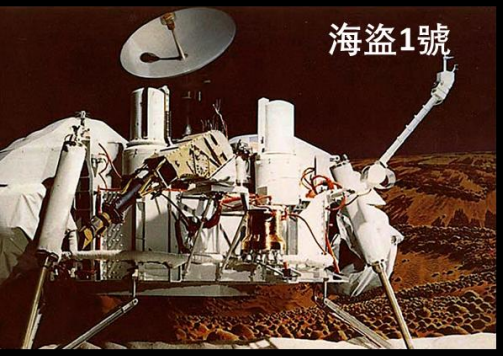
巧欺淫诳，幽阳以别。无隈无隅，曷懵厥列。

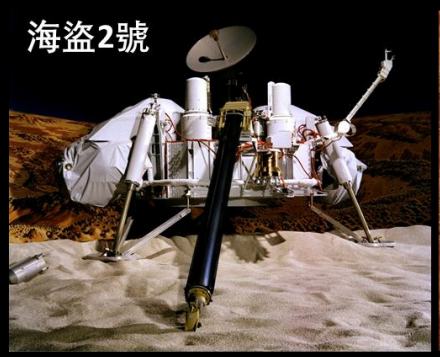

央视新闻
中国首次火星探测任务名称为
天问一号
(Tianwen-1)
China’s first Mars exploration mission is named as “Tianwen-1”

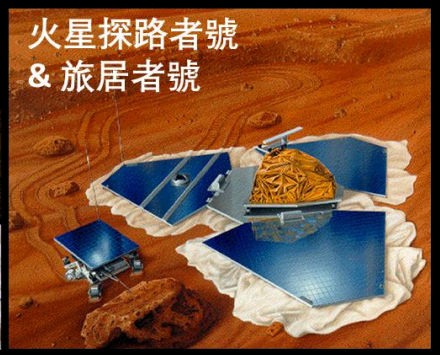

央视新闻
将行星探测任务命名为
天问
(Tianwen)系列
while Tianwen series are names given to planetary missions.

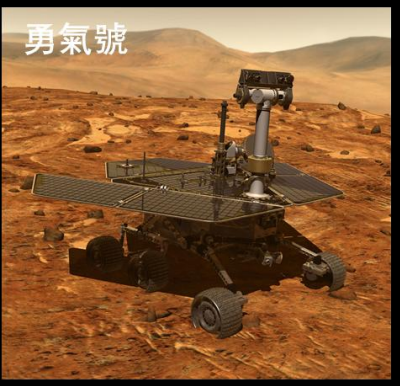
中国行星探测
PEC

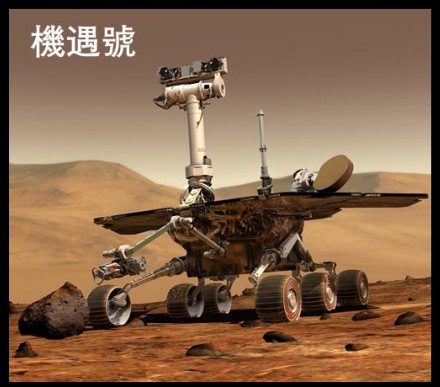

中新视频

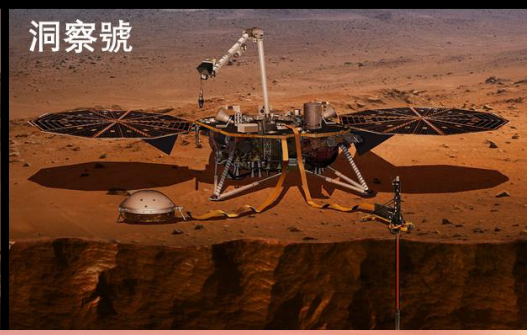


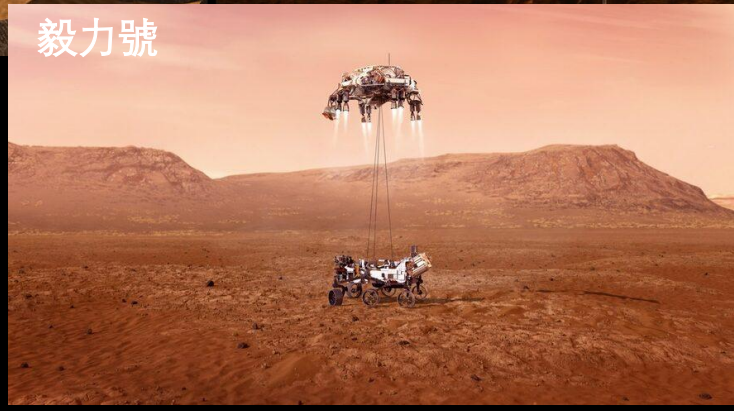




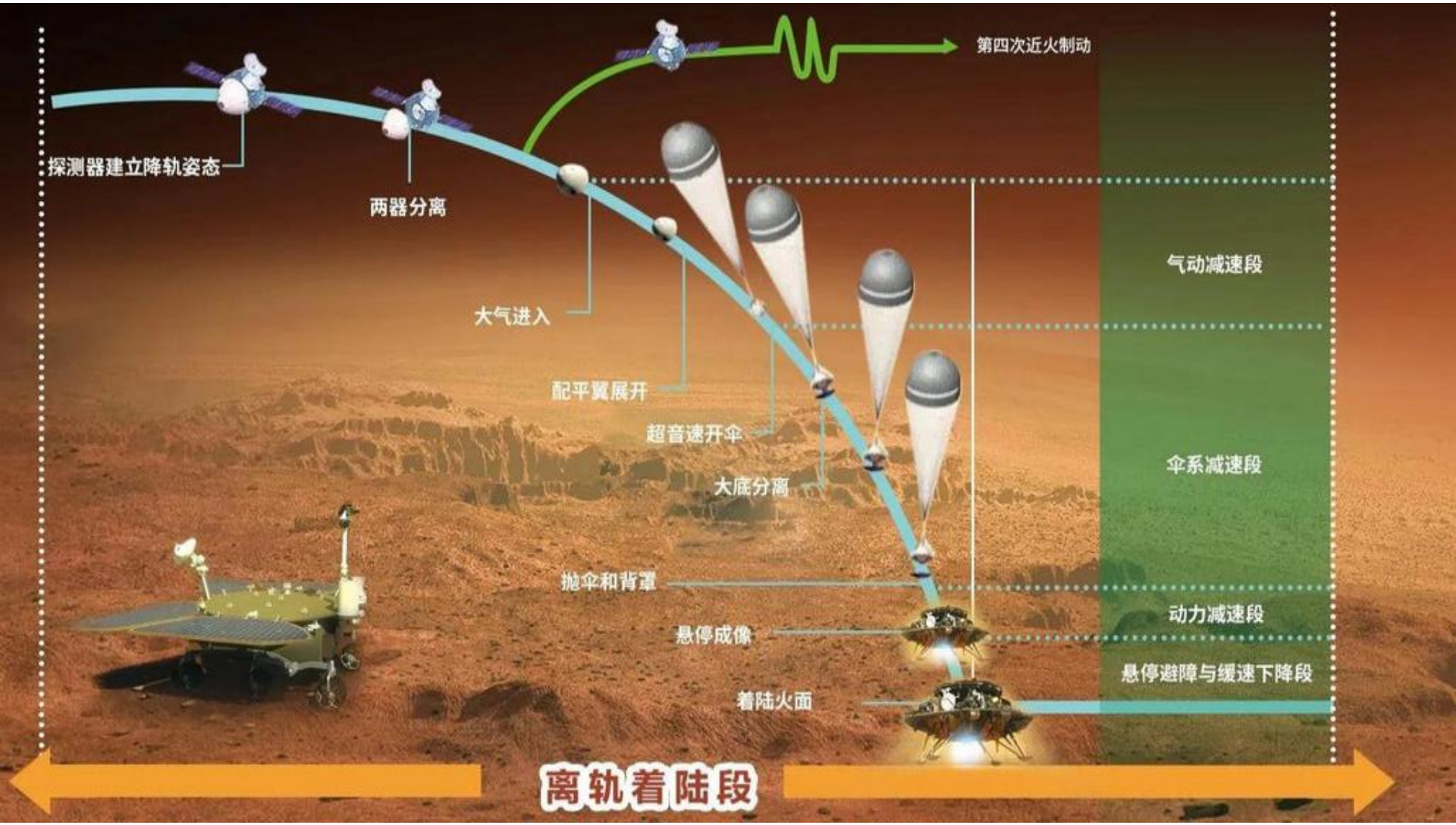




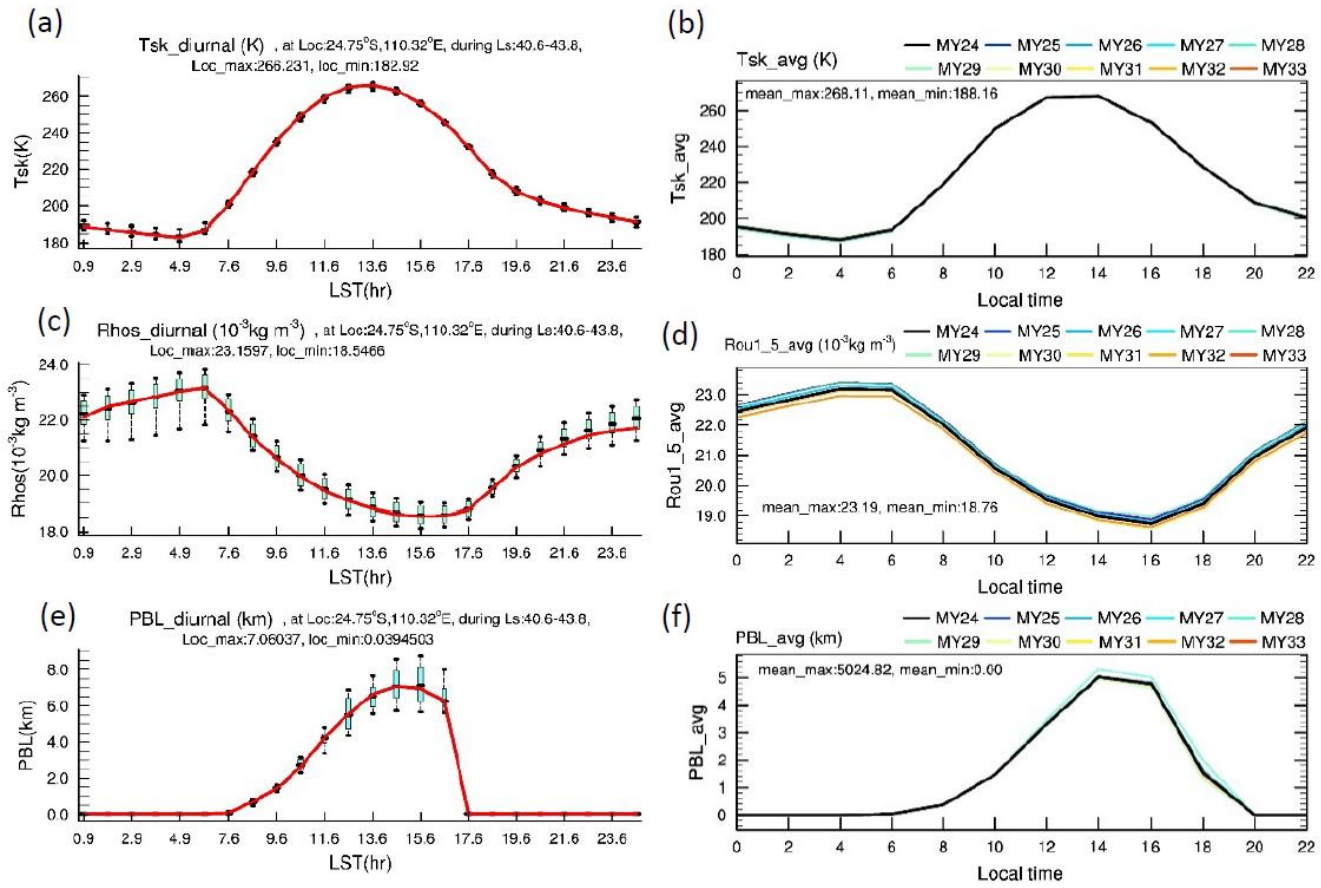




目前九次成功的火星著陸任務


第四次近火制动
探测器建立降轨姿态
两器分离
大气进入
配平翼展开
超音速开伞
大底分离
抛伞和背罩
悬停成像
着陆火面
气动减速段
伞系减速段
动力减速段
悬停避障与缓速下降段
离轨着陆段

什麼時候最適合著陸？— 火星天氣預報



什麼時候最適合著陸？— 火星天氣預報

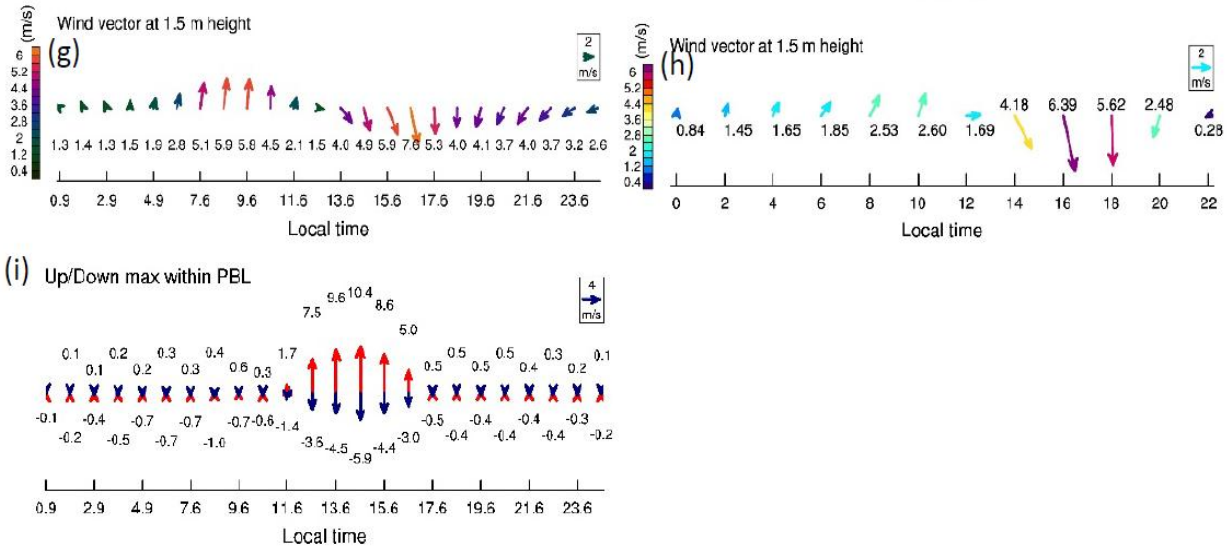


图 **2** MarsWRF 模式 D05 区域地表变量场（左列）与 MCD5.3 再分析数据 D05 区域地表气象场多年日变化（右列）。其中(a)(b) Tsk 为地表温度(K); (c)(d) Rhos 为地表空气密度(10^{-3}kg·m^{-3}); (e)(f) PBL 为对流边界层厚度(km)，其指示了对流活动的平均最大高度; (g)(h) 1.5m 高度的水平风矢量(m/s); (i)对流边界层中最大上升、下沉速度(m/s)。上述(a)(c)(e)(g)(i)为模式完全 inter-active 起沙辐射方案第 2 年 Sol:85~91 的统计结果，其中部的粗短线为平均值，填色柱为 5%~95%信度区间值，虚线延长线两端为极端值，红色粗线为着陆点 A 处值。(b)(d)(f)(h)中不同颜色为 MCD5.3 第 24~33 个火星年 Sol:78-98 时段平均结果，黑色粗线为多年平均值。

著陸路徑如何？— 火星大氣參數

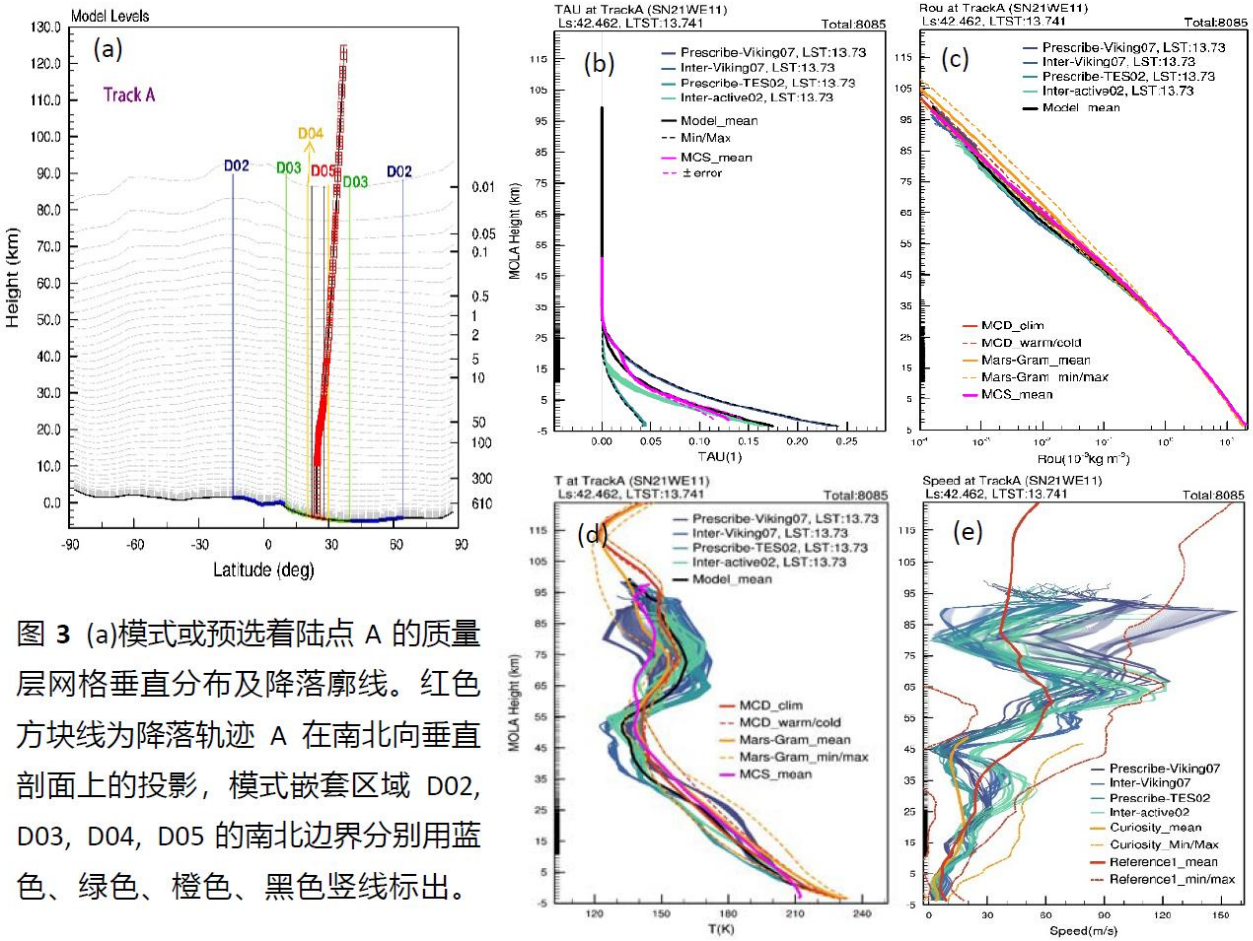


图 **3** (a)模式或预选着陆点 A 的质量层网格垂直分布及降落廓线。红色方块线为降落轨迹 A 在南北向垂直剖面上的投影，模式嵌套区域 D02, D03, D04, D05 的南北边界分别用蓝色、绿色、橙色、黑色竖线标出。

Why Physics ?

Physics changes our life

Internet (world wide web) (万维网)

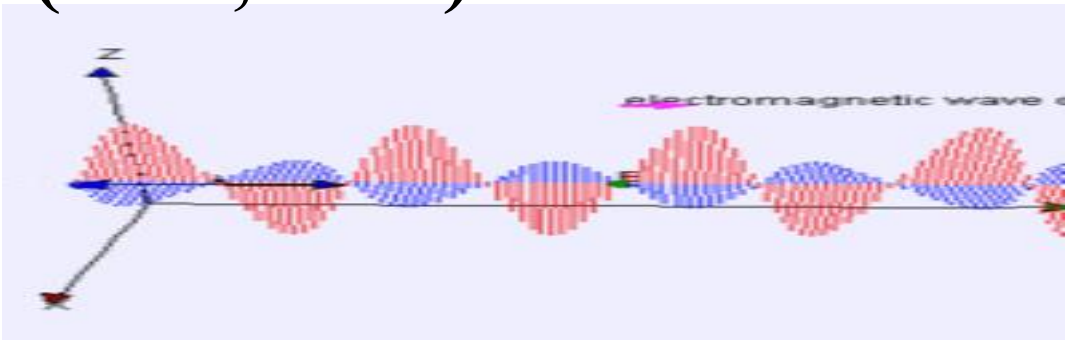
25 December 1990

This NeXT Computer was used by Tim Berners-Lee at CERN and became the world's first Web server.

Mobile platform （移动平台）

Electro-magnetic wave （电磁波）

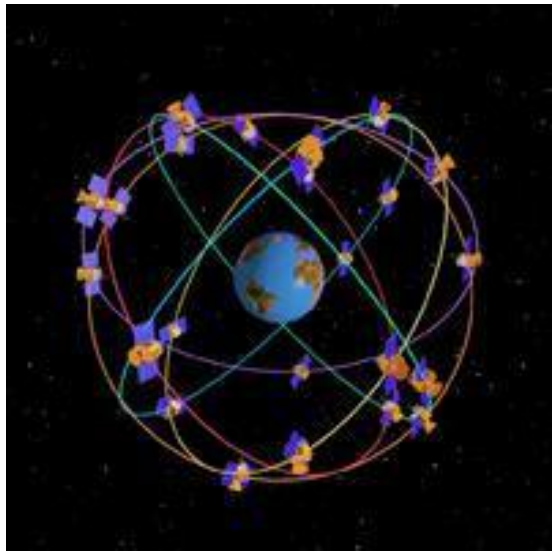
(1864, 1887)

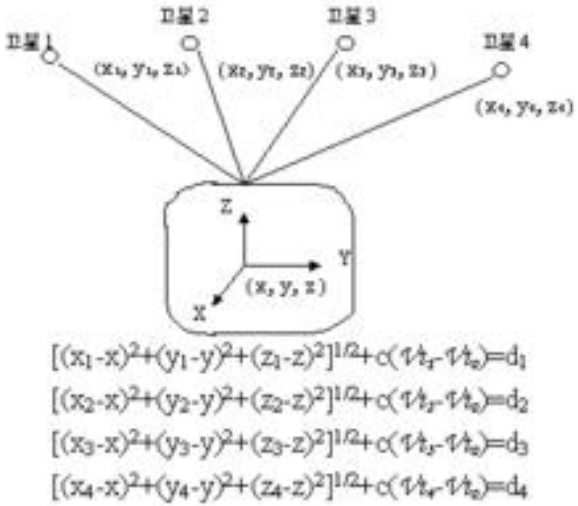


Why Physics ?

Mobile platform（移动平台）

Global Positioning System，**GPS**（全球定位系统），手机地图





Why Physics ?

Scientific thinking ability you can get (科学思维, 解决复杂问题)

How to realize the problem

Analyze the problem

Model the problem

Example: investment （投资）

(Financial Physics)

Statistic physics （统计物理）

Theoretical physics （理论物理）

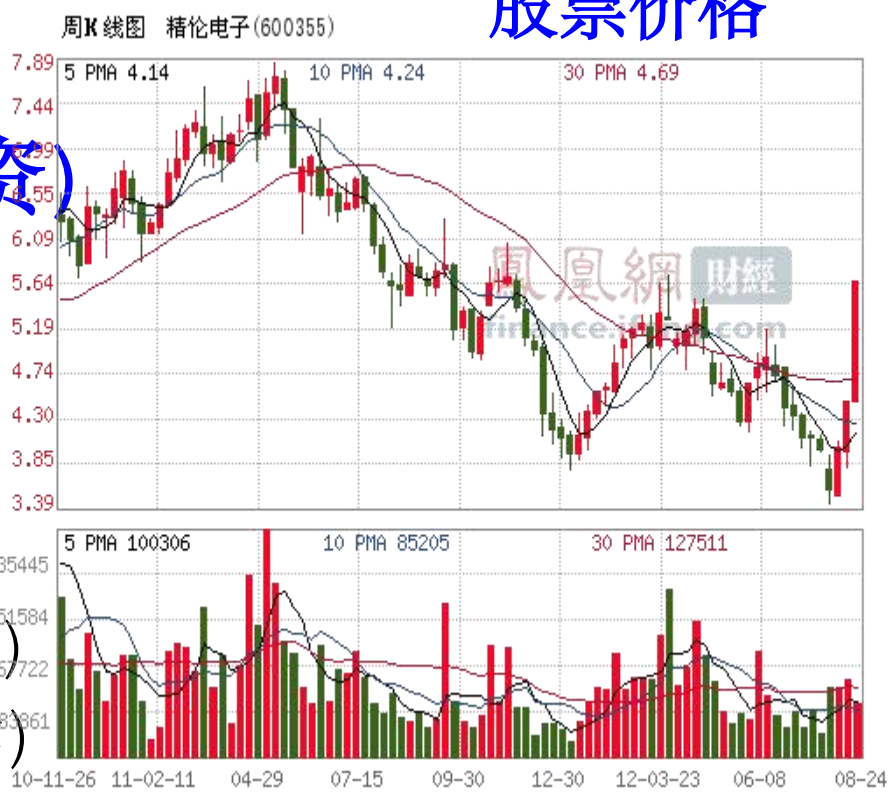
Theory of complicate system

Non-linear science （非线性科学）

Applied mathematics （应用数学）

How to model the curve?

股票价格



Physics is the most fundamental science

- **Physics is the most fundamental of the sciences, Chemistry (化学), Astronomy (天文), Geology (地质学), Computer (计算机)…**

  physical concepts (物理概念), terms,

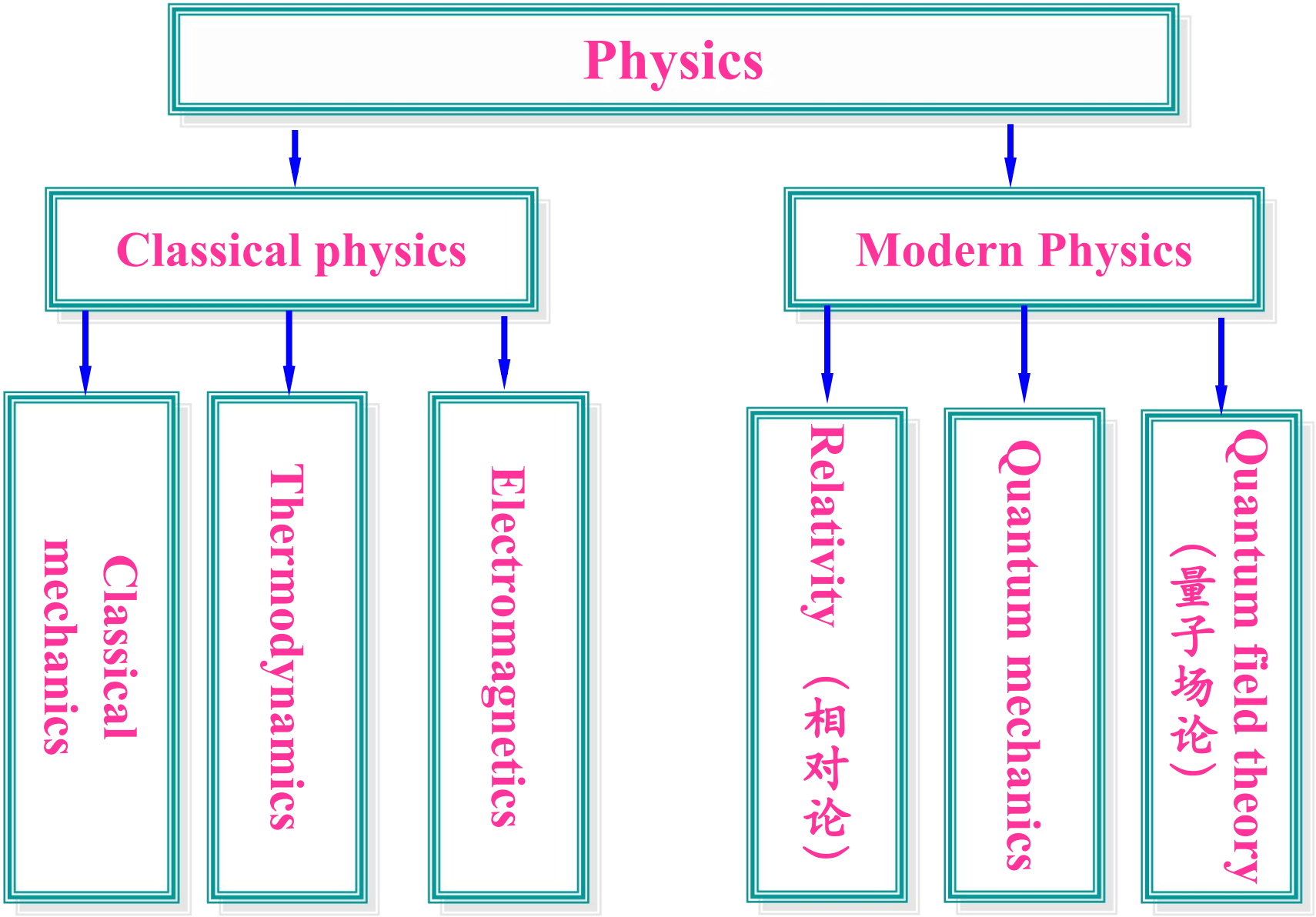
  means of research (研究方法), instrument…

- **No theory in other science can exist against physical law.**

Refer to Feynman Lectures on Physics (Vol.1)

Contents

Classification of Physics （物理分类）



Reference Books:

1. 物理学基础（第六版), Halliday, Resnick, Walker 著, 张三慧, 李椿等译。机械工业出版社。
2. 大学物理学 （第三版），张三慧 主编。清华大学出版社。
3. 大学物理学(第三版)学习辅导与习题解答，张三慧主编。清华大学出版社。
4. 大学物理学，卢德馨著。高等教育出版社。
5. 费恩曼物理学讲义（中文版）， 费恩曼，莱顿，桑兹 著，郑永令， 华宏鸣， 吴子仪 等译。上海科学技术出版社。

Chapter 1-2

Coordinate system: 坐标系

Reference frame: 参考系

Position : 位置

Displacement : 位移

Distance: 路程

Instantaneous velocity: 瞬时速度

Component: 分量

Vector: 矢量

Scalar: 标量

Acceleration: 加速度

Centripetal: 向心的

Tangential: 切向的

Kinematics: 运动学

Dynamics: 动力学

Chapter 1 : Measurement

How to measure a physical quantity?

We measure each quantity by its own "unit" or by comparison with a standard.

How to select base quantities and base standards?

Base standards must be both accessible and invariable.

Invariability is first!

The International System of Units (SI)

Quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Length

meter — distance traveled by light in a vacuum during a time of 1/299 792 458 second.

Time

second — 9 192 631 770 times the period of oscillation of radiation from the cesium-133 atom.

Mass

kilogram — mass of a specific platinum-iridium alloy cylinder kept at the International Bureau of Weights and Measures, France.

Derived quantities and derived units

(导出量和导出单位)

speed: $v = \dfrac{s}{t}$ **m/s**

density: $\rho = \dfrac{m}{V}$ **kg/m^3**

Dimension (量纲)

$$[v] = [s]/[t] = LT^{-1}$$

$$[\rho] = [m]/[V] = ML^{-3}$$

Chapter 2: Kinematics 1

— Motion along a straight line

All matters, large as celestial bodies, small as atoms and elementary particles, are in constant motion.

Mechanics deals with mechanical motion of objects, its description, causes and laws.

Kinematics: the description of motion.

Dynamics: the relation of motion to its causes.

Idealized model: **A model is a simplified substitute for the real problem that allows us to solve the problem in a relatively simple way.**

The particle model （质点模型）

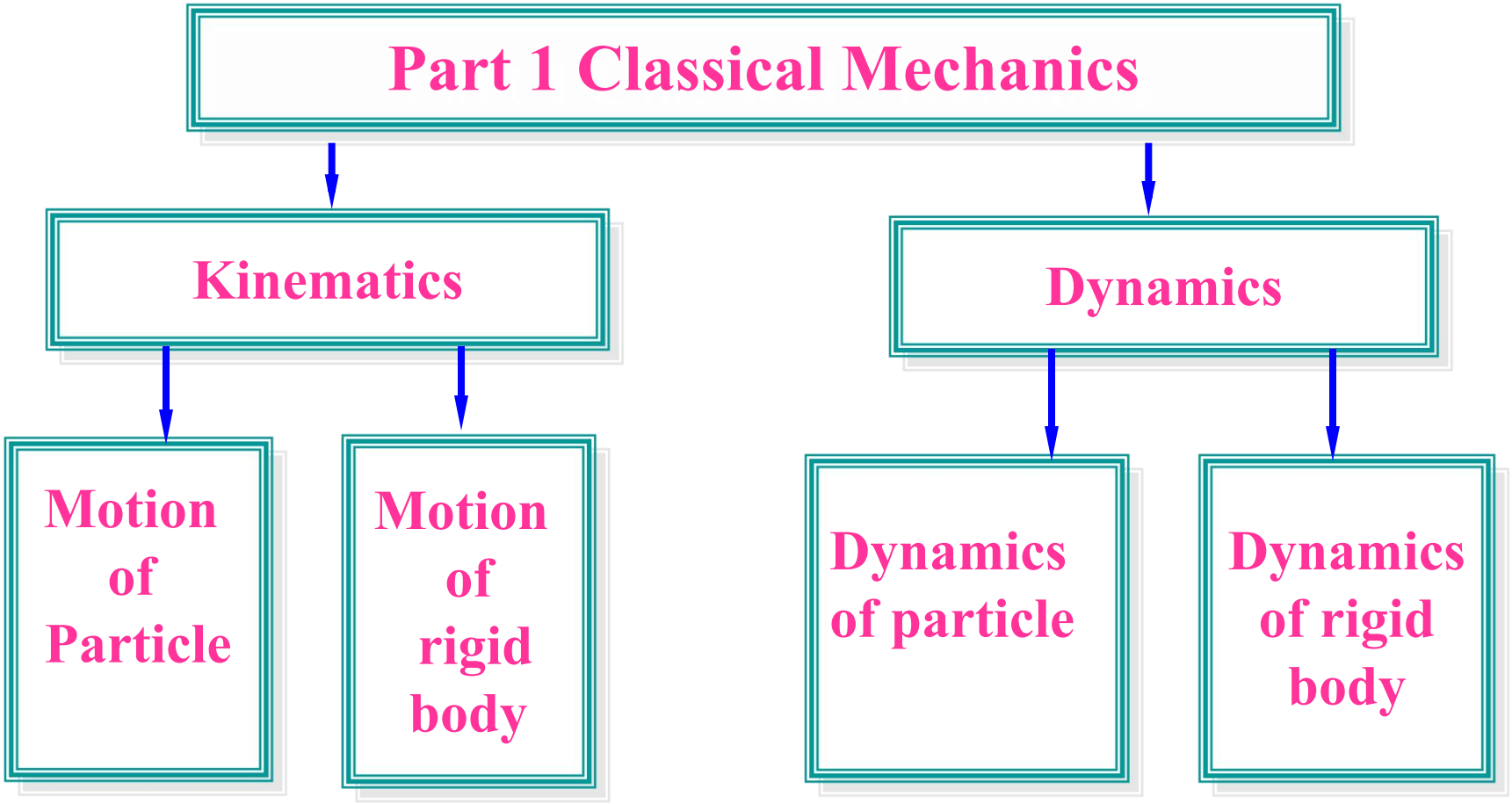
The particle has mass, but zero size.

The condition for using the particle model

- **the size of the actual object is of no consequence in the analysis of its motion**
- **any internal processes occurring in the object are of no consequence in the analysis of its motion**

the Earth's revolution around the Sun (√)

the Earth's rotation about its axis (x)


Part 1 Classical Mechanics
Kinematics
Dynamics
Motion of Particle
Motion of rigid body
Dynamics of particle
Dynamics of rigid body

Reference frame （参考系）

To measure/describe the state of motion of an object (position, velocity, acceleration).

Observers in different reference frames may measure different velocities or accelerations.

Observer in the truck: a vertical path

Observer in the Earth: projectile motion

Coordinate system

(坐标系)

Position and motion function:

Position of a particle: x

$x(0)=31\text{m}$, $x(10)=52\text{m}$,
$x(20)=38\text{m}$, $x(30)=0\text{m}$,
$x(40)=-38\text{m}$, $x(50)=-42\text{m}$

Motion function:

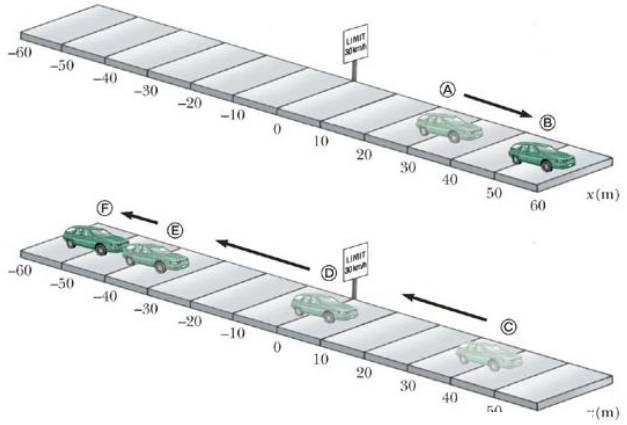
position function of time

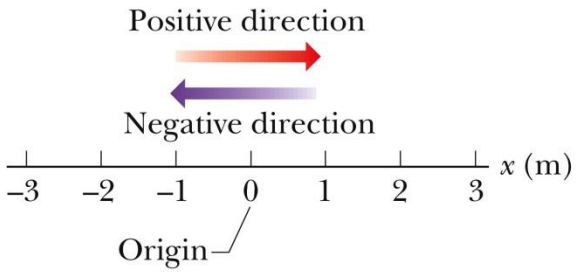
$$x=x\,(t)$$

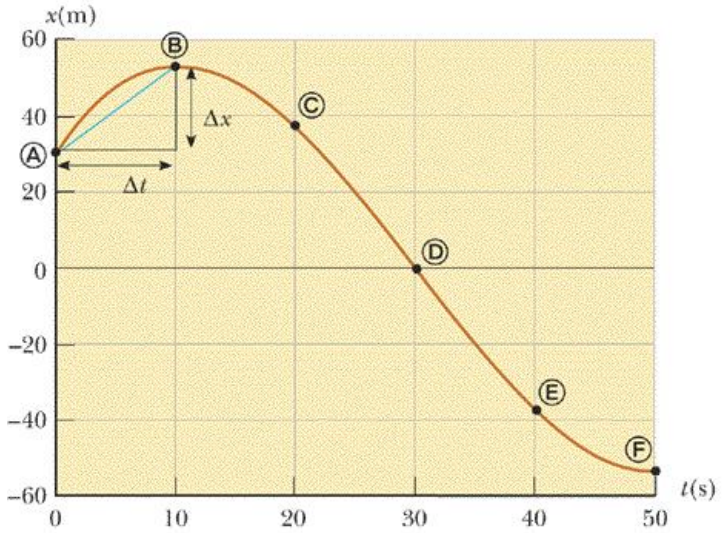
Position-time graph:

horizontal axis—t

vertical axis—x

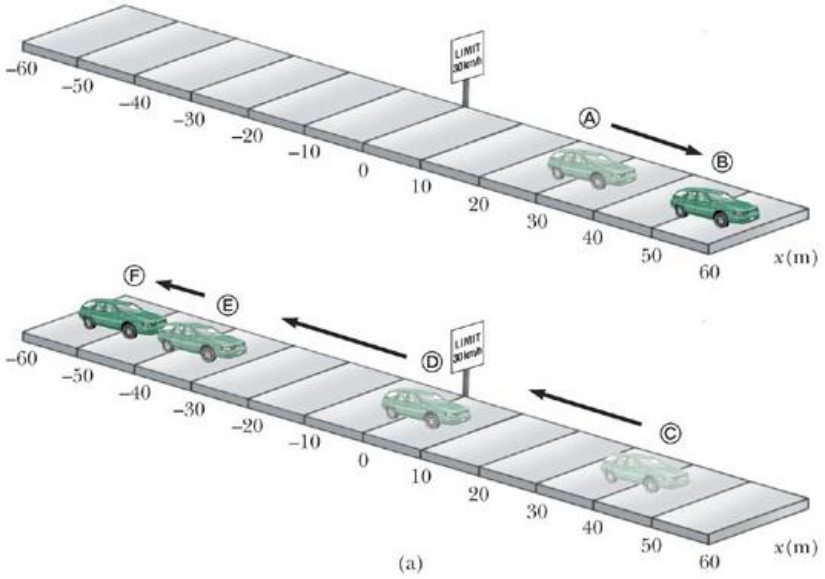






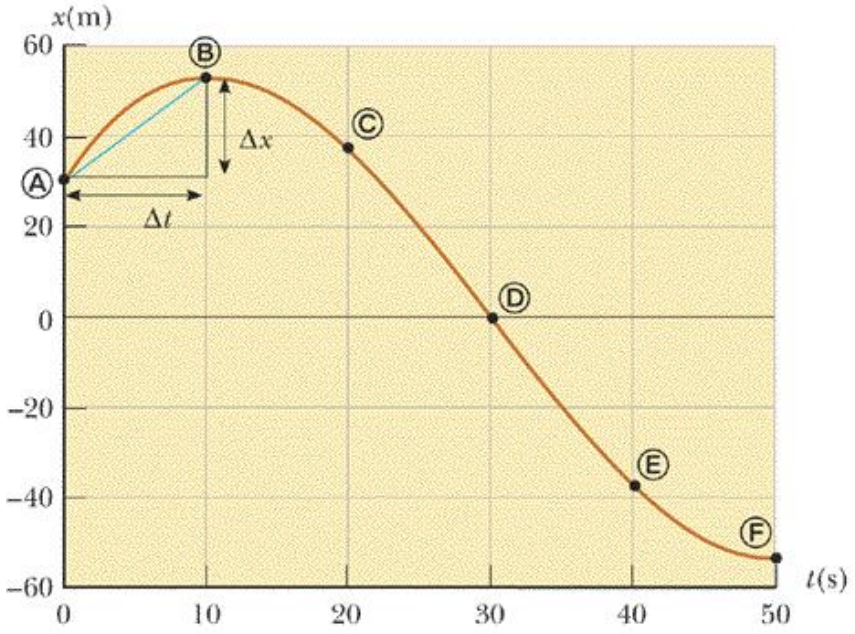
Displacement: （位移）

a change from position x_1 to position x_2 during the time interval Δt



$x(0)=31\text{m}$, $x(10)=52\text{m}$,
$x(20)=38\text{m}$, $x(30)=0\text{m}$,
$x(40)=-38\text{m}$, $x(50)=-42\text{m}$

$$\Delta x(0 \to 10) = x(10) - x(0) = 52 - 31 = 21m$$
$$\Delta x(10 \to 20) = x(20) - x(10) = 38 - 52 = -14m$$
$$\Delta x(0 \to 20) = x(20) - x(0) = 38 - 31 = 7m$$



Distance: （路程）

$$d(0 \to 10) = x(10) - x(0) = 52 - 31 = 21m$$
$$d(10 \to 20) = |x(20) - x(10)| = |38 - 52| = 14m$$
$$d(0 \to 20) = |x(10) - x(0)| + |x(20) - x(10)|$$
$$= 21 + 14 = 35m$$

Displacement is a vector, has both a magnitude and a direction

For one dimension motion:

the absolute value signifies the magnitude

the sign signifies the direction

$$\Delta x = x(20) - x(10) = 38 - 52 = -14m$$

Distance is a scalar, has only a magnitude

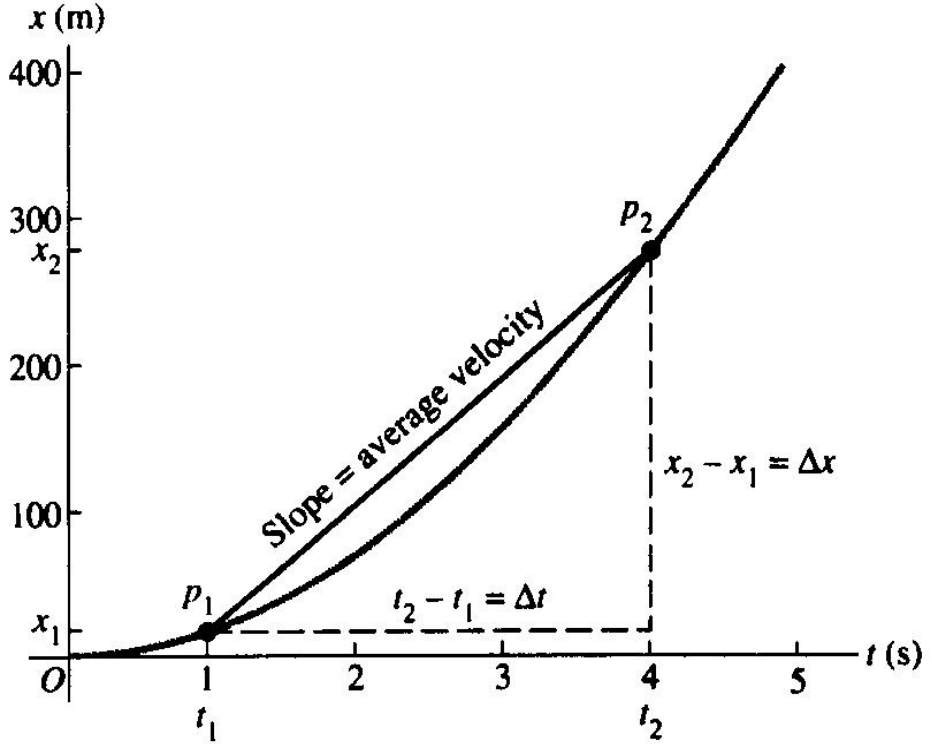
The magnitude of the displacement is not always equal to the distance

$$|\Delta x| = |x(10) - x(0)| = 21m, \qquad d(0 \to 10) = 21m$$
$$|\Delta x| = |x(20) - x(0)| = 7m, \qquad d(0 \to 20) = 35m$$

Velocity and speed （速度與速率）

- **Average velocity**
  is defined as the ratio of the displacement of the particle to the time interval.

$$\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t} = \frac{\text{displacement}}{\text{time interval}}$$



- **Average speed**

is defined as total distance divided by the time interval

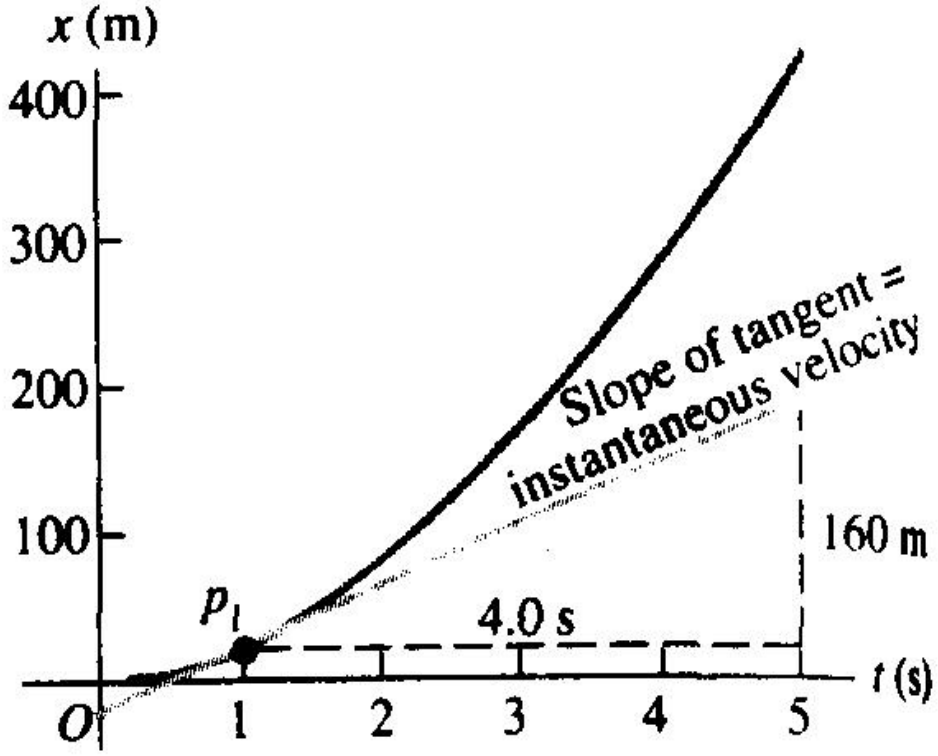
$$\bar{s} = \frac{\text{distance}}{\text{time interval}}$$

•Instantaneous velocity

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

The instantaneous velocity equals the derivative of x with respect to t

- The average velocity approaches the instantaneous velocity as $\Delta t \to 0$.
- Represented by the slope of tangent at point p_1.



•Instantaneous speed

$$s = \frac{|dx|}{dt} = \left|\frac{dx}{dt}\right| = |v|$$

(Instantaneous) speed is the magnitude of the (instantaneous) velocity.

Classwork:

If a particle's position is given by $x=3t-4t^2+t^3$, where x is in meter and t in second. Find

(a) the positions of this particle at 1s,2s,3s,and 4s;

(b) displacement between t=0s and t=4s;

(c) average velocity from t=2s to t=4s;

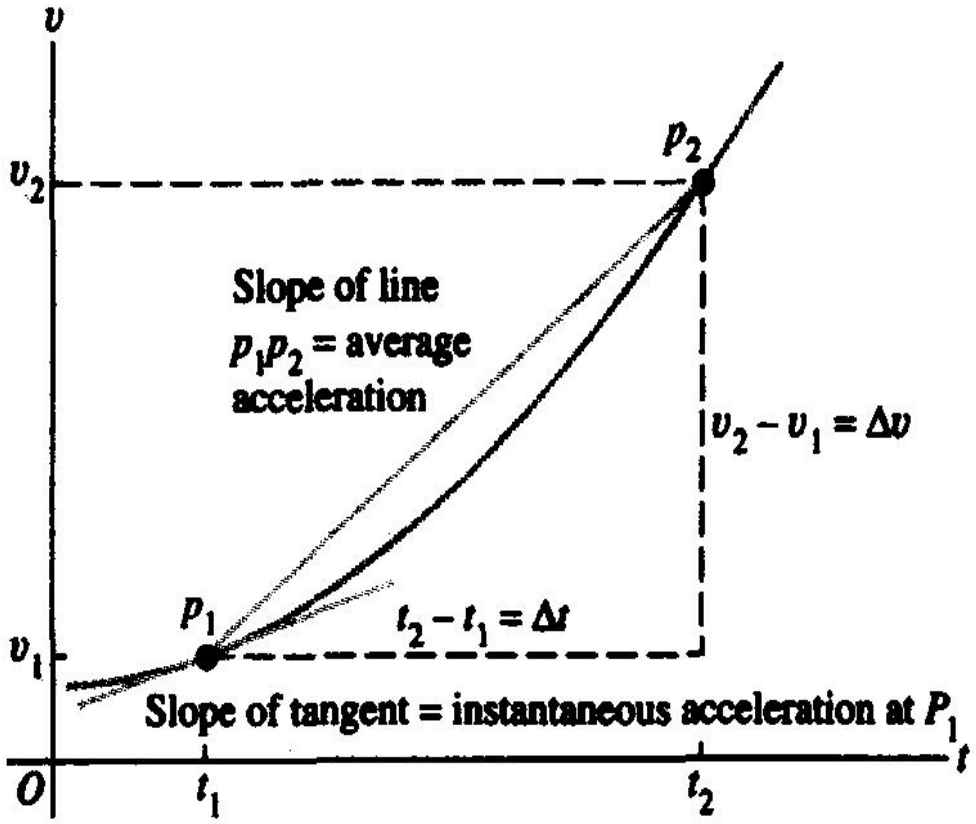
(d) average speed from t=2s to t=4s;

(e) instantaneous velocity at 2s.

Acceleration

- **Average Acceleration:** is defined as the ratio of the change in the velocity to the time interval.

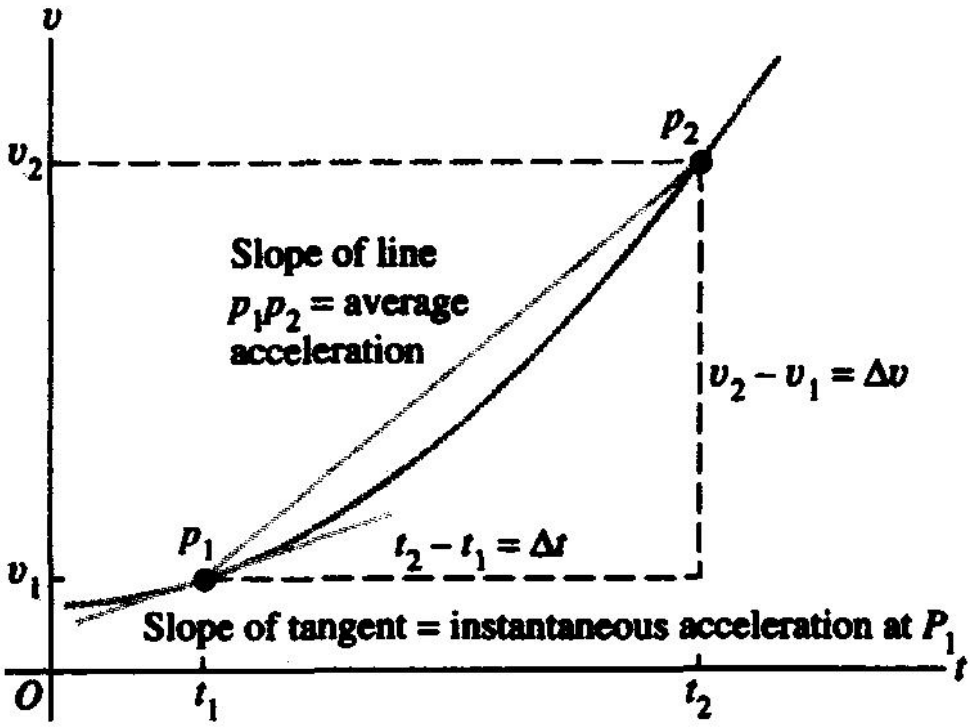
$$\bar{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$



- In v-t graph, average acceleration is represented by the slope of the chord p_1p_2.
- Choose different time intervals, lead to different average accelerations.

- **Instantaneous Acceleration**

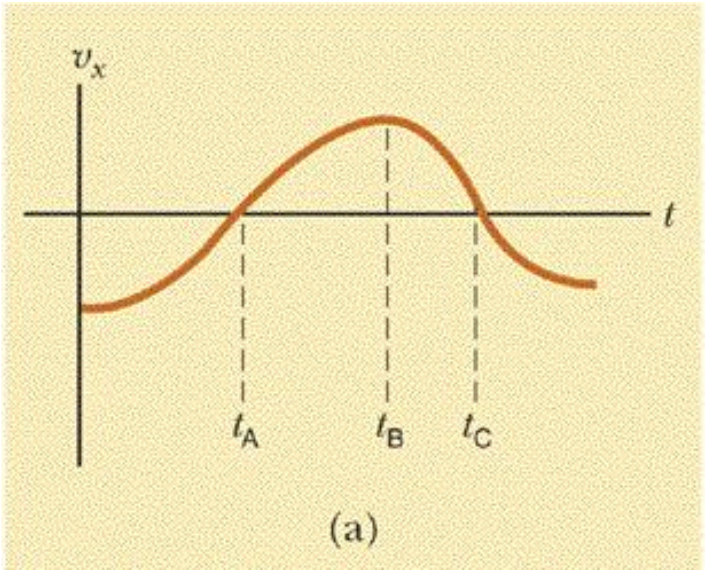
$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

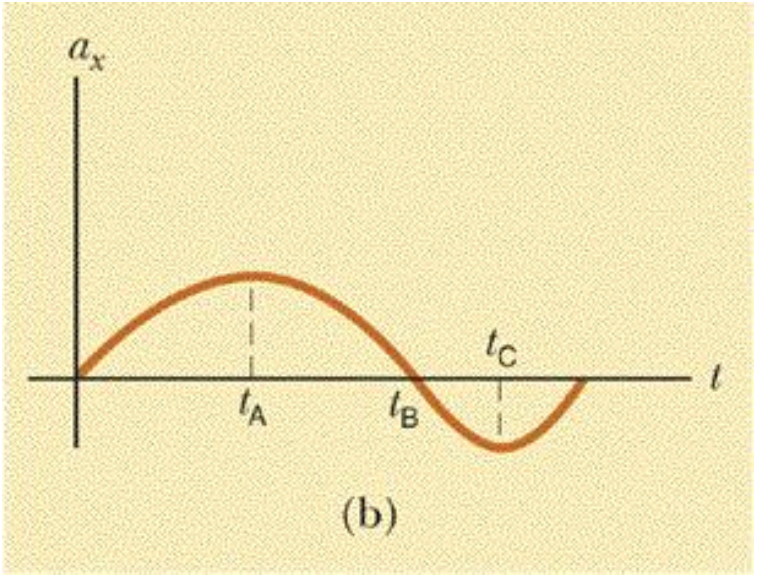


- Represented by the slope of tangent at point p_1.
- The instantaneous acceleration equals to the second derivative of the position x with respect to time t.

Relationship between velocities and accelerations

If a particle has the same sign for velocity and acceleration, then that particle is speeding up.
Conversely, if a particle has opposite signs for the velocity and acceleration, then the particle is slowing down.





Constant acceleration

When the acceleration is constant, its average and instantaneous values are the same.

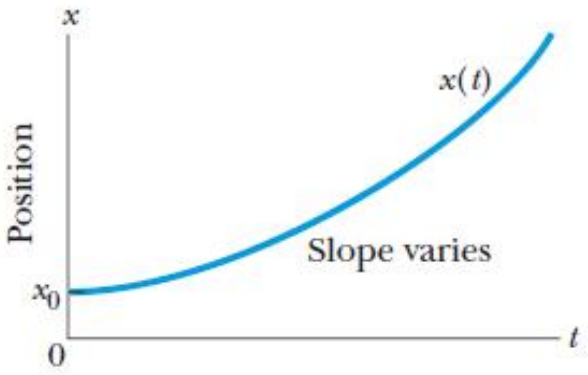
$$a = \bar{a} = \frac{v - v_0}{t - 0} \qquad \text{where} \quad v_0 = v(t = 0)$$

i.e., $v = v_0 + at$ $\qquad \bar{v} = \dfrac{v + v_0}{2}$

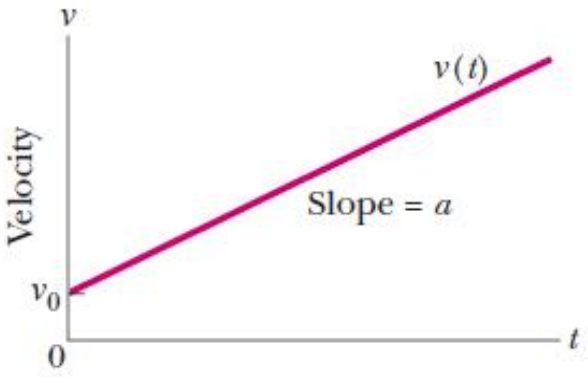
$$x - x_0 = \bar{v}t = \frac{v_0 + v_0 + at}{2}t = v_0 t + \frac{1}{2}at^2$$

By eliminating t, we obtain

$$v^2 = v_0^2 + 2a(x - x_0)$$



(a)



(b)

(c)

Slopes of the position graph are plotted on the velocity graph.

Slope of the velocity graph is plotted on the acceleration graph.

Another look at constant acceleration motion

Starting from $a = \frac{dv}{dt}$

we obtain $dv = adt$

$$\int_{v_0}^{v} dv = a\int_{0}^{t} dt \quad \Rightarrow v - v_0 = at$$

$$\int_{x_0}^{x} dx = \int_{t_0}^{t} vdt = \int_{0}^{t} (v_0 + at)dt \quad \Rightarrow x - x_0 = v_0 t + \frac{1}{2}at^2$$

$$\frac{dv}{dt} = \frac{dv}{dx}\frac{dx}{dt} = v\frac{dv}{dx} = a$$

$$\int_{v_0}^{v} vdv = a\int_{x_0}^{x} dx \quad \Rightarrow v^2 - v_0^2 = 2a(x - x_0)$$

Motion with variable acceleration

Starting from $a(t) = \frac{dv(t)}{dt}$

we obtain $dv(t) = a(t)dt$

$$\int_{v_0}^{v} dv(t) = \int_{0}^{t} a(t)dt \quad \Rightarrow v(t) = v_0 + \int_{0}^{t} a(t)dt$$

$$\int_{x_0}^{x} dx = \int_{t_0}^{t} v(t)dt = \int_{0}^{t} \left[v_0 + \int_{0}^{t} a(t)dt \right] dt$$

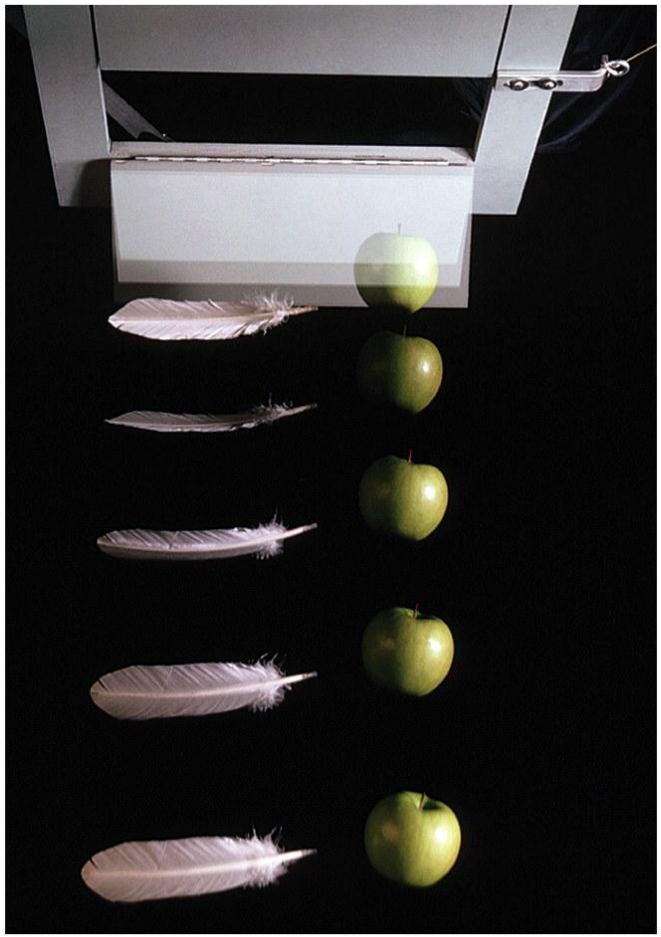
$$\Rightarrow x = x_0 + v_0 t + \int_{0}^{t} \left[\int_{0}^{t} a(t)dt \right] dt$$

$$\frac{dv}{dt} = \frac{dv}{dx}\frac{dx}{dt} = v\frac{dv}{dx} = a(t)$$

$$\int_{v_0}^{v} v dv = \int_{x_0}^{x} a(t)dx \quad \Rightarrow v^2 - v_0^2 = \int_{x_0}^{x} a(t)dx$$

Free-Fall acceleration (自由落體運動)

In vacuum (真空), no air, $a = -g = -9.8 m/s^2$



Sample problem 1

Free-Fall acceleration: $a=-g=-9.8\ m/s^2$

A pitcher tosses a baseball up along the y axis, with an initial speed of 12 m/s.

(a) How long does the ball take to reach its maximum height?

(b) What is the ball's maximum height above its release point?

(c) How long does the ball take to reach a point 5.0 m above its release point?

Analysis:

1. Constant acceleration a=-g
2. Initial speed 12m/s

Solution:

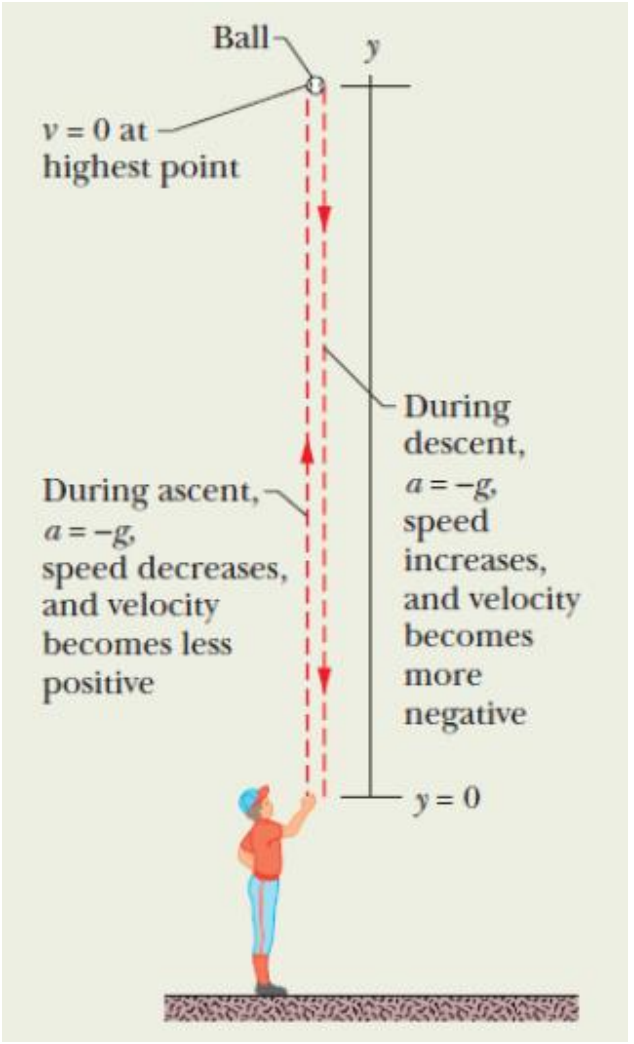
(a) $$t = \frac{v - v_0}{a} = \frac{0 - 12 m/s}{-9.8 m/s^2} = 1.2 s$$

(b) $$y = \frac{v^2 - v_0^2}{2a} = \frac{0 - 12^2}{2(-9.8)} = 7.3\ m$$

(c) $$y = v_0 t - \frac{1}{2} g t^2 \Rightarrow$$

$$5 = 12t - 4.9t^2$$

$$t = 0.53 s \ \text{ and } \ 1.9 s$$



Classwork 1

Free-Fall acceleration: $a=(-10 + t)\ m/s^2$ $(t < 10\ s)$

A pitcher tosses a baseball up along a y axis, with an initial speed of 12 m/s.

(a) How long does the ball take to reach its maximum height?

(b) What is the ball's maximum height above its release point?

(c) How long does the ball take to reach a point 5.0 m above its release point?

Analysis:

1. Acceleration a=(-10 + t) m/s^2
2. Initial speed 12m/s

Solution:

(a) $\int_{v_0}^{v(t)} dv = \int_0^t a(t)dt$

$$v(t) - v_0 = \int_0^t (-10 + t)dt = -10t + \frac{t^2}{2}$$

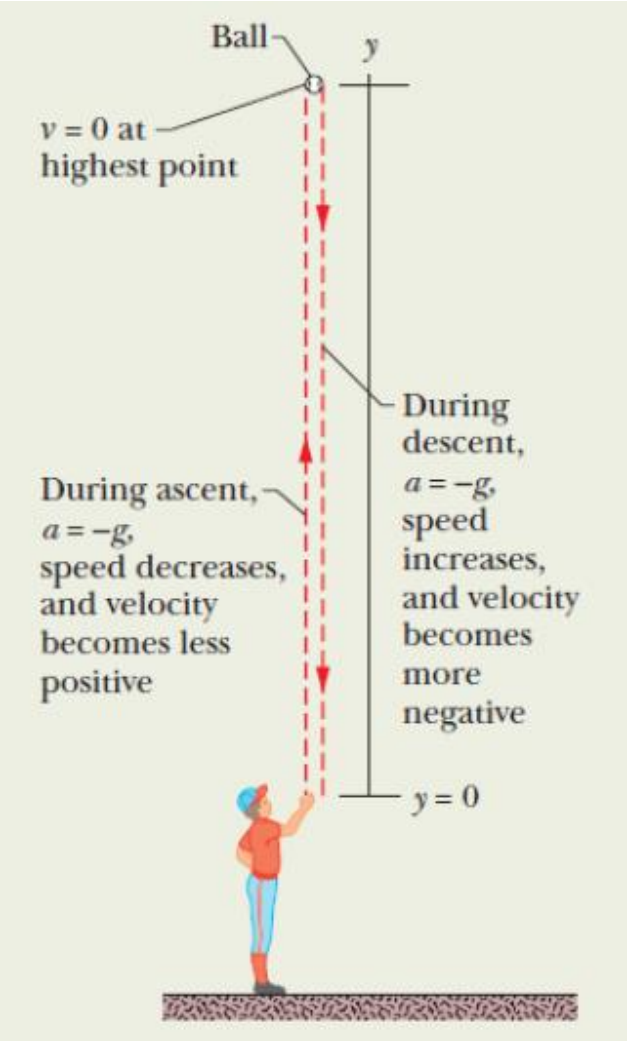
Maximum height: $v(t) = 0$

$v_0 = 12$ m/s

$t = 10 \pm 2\sqrt{19}$ s

$t_1 = 1.28$ s

$t_2 = 18.72$ s



(b)

$$\int_{v_0}^{v(t)} dv = \int_0^t a(t)dt$$

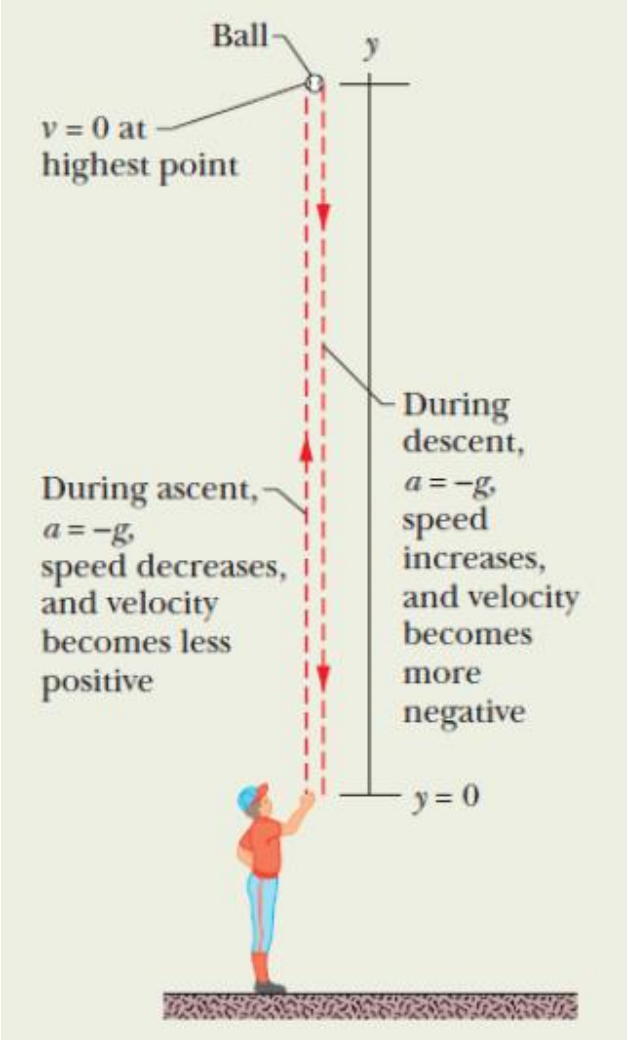
$$v(t) - v_0 = \int_0^t (-10 + t)dt = -10t + \frac{t^2}{2}$$

$$v(t) = v_0 - 10t + \frac{t^2}{2}$$

$$\int_0^{x(t)} dx = \int_0^t v(t)dt = \int_0^t (v_0 - 10t + \frac{t^2}{2})dt$$

$$x(t) = v_0 t - 5t^2 + \frac{t^3}{6}$$

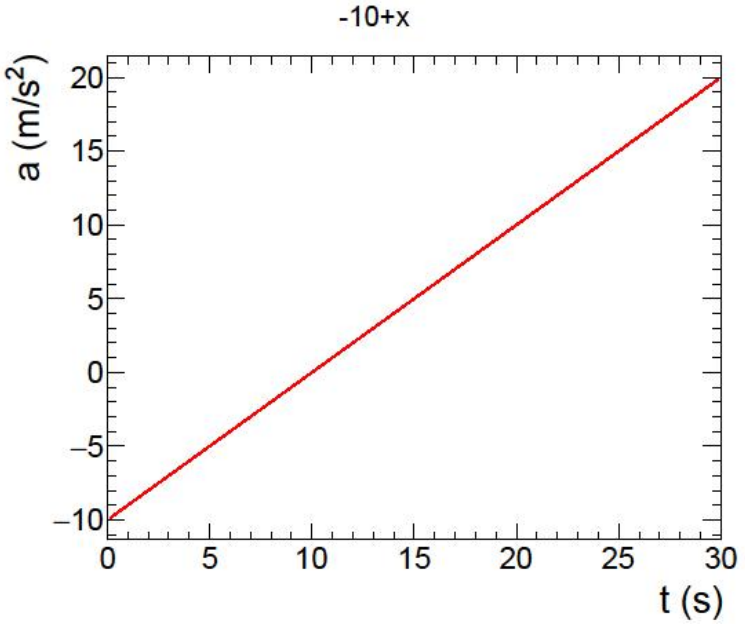
Maximum height: at t_1=1.28 s $x = 7.52$ m

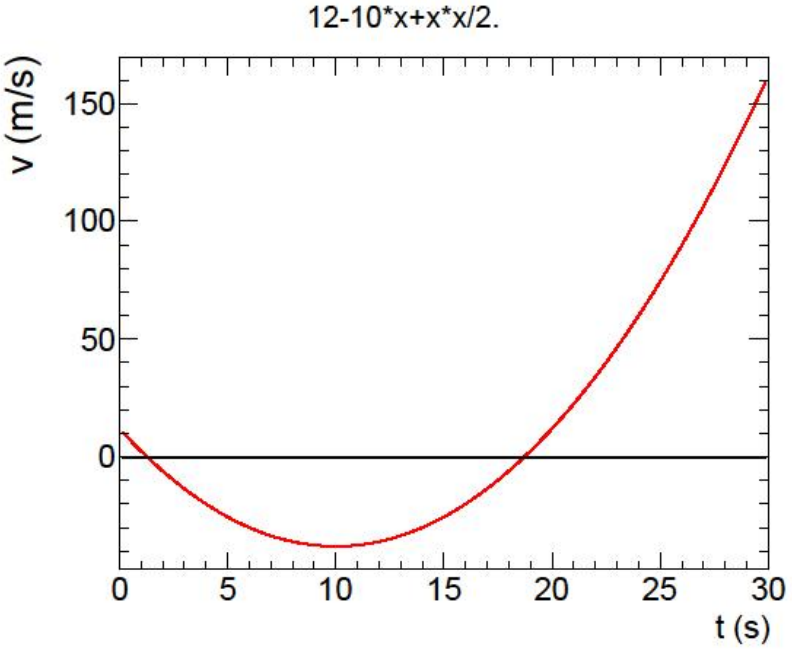


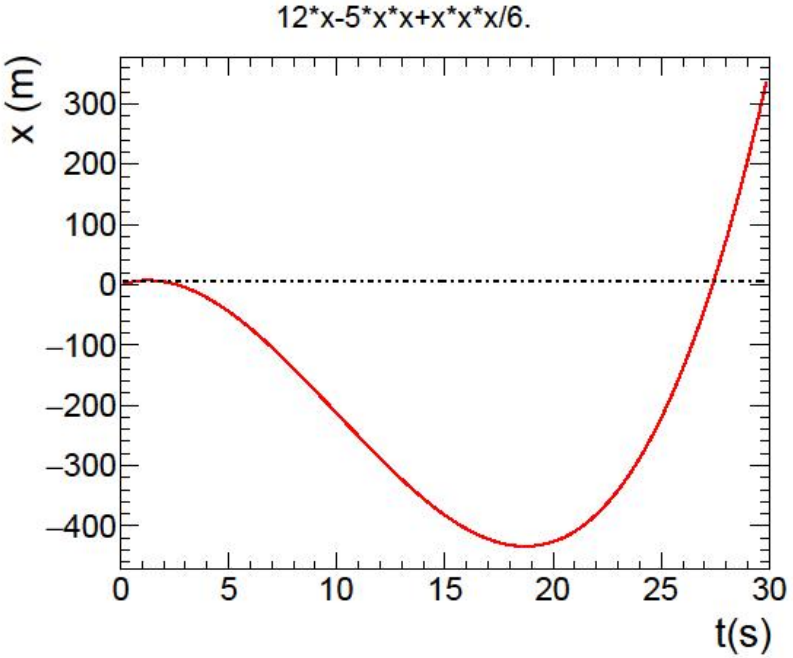
(c)

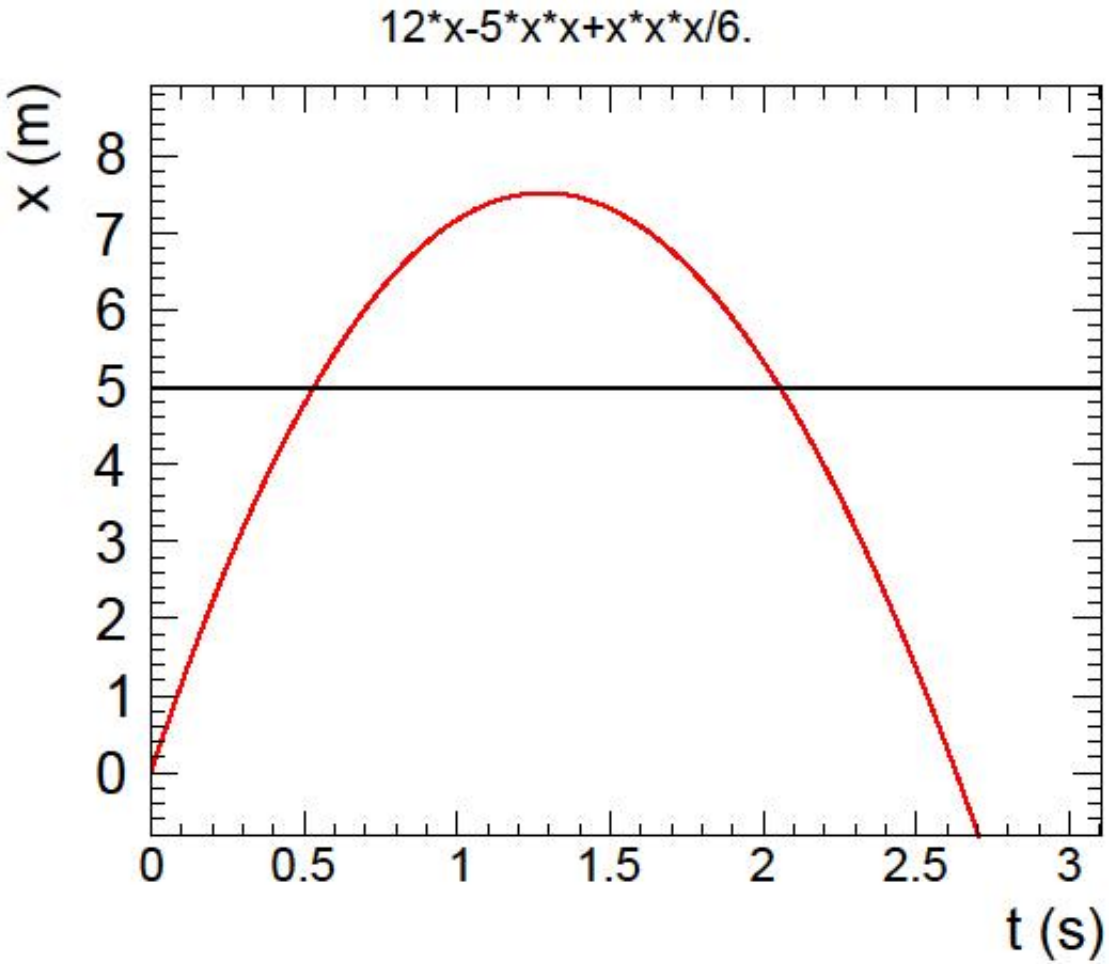
$$x(t) = v_0 t - 5t^2 + \frac{t^3}{6} = 5$$

t_1=0.53 s; t_2=2.05 s; $t_3 = 27.41$ s








12*x-5*x*x+x*x*x/6.
x (m)
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
t (s)

Why the safe distance between two cars in the highway is 100-200 meters? Is it reasonable?

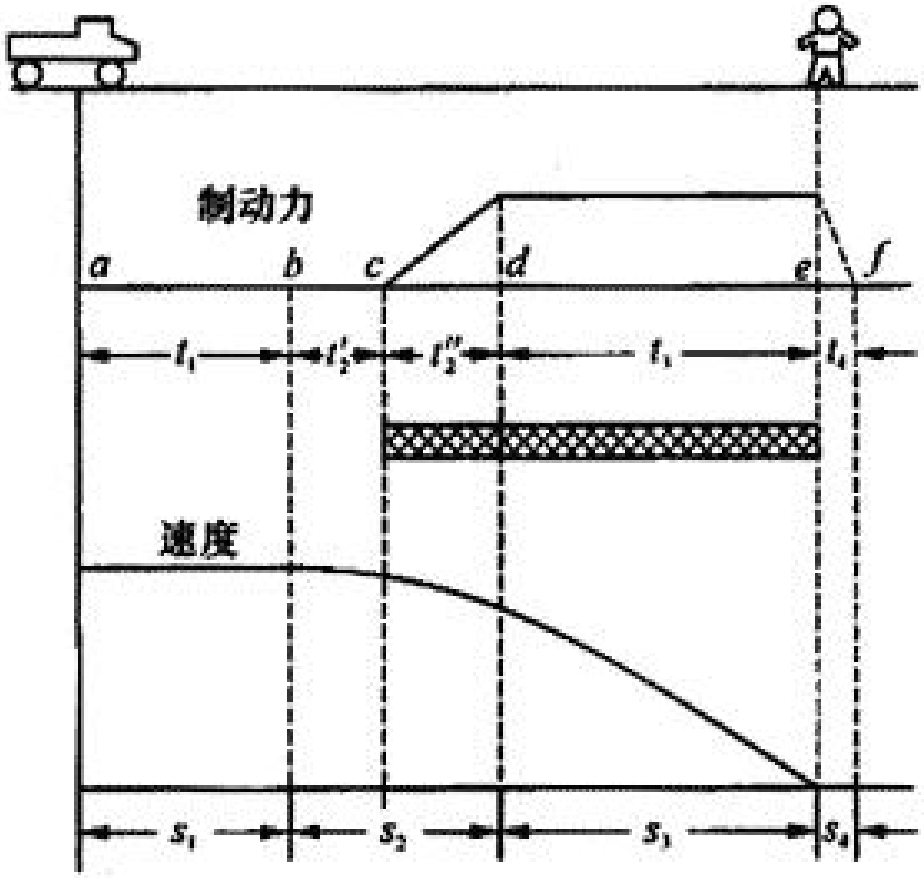


图 1－6　制动全过程

路面	附着（摩擦）系数	行驶速度（km/h）								
		10	20	30	40	50	60	70	80	90
		制动距离 (Reaction time not included) (米)								
干沥青与混凝土路面	0.7 ~ 0.8	0.49	1.97	4.40	7.85	12.30	17.75	24.00	31.50	39.90
干碎石路面	0.6 ~ 0.7	0.65	2.65	6.90	10.50	16.40	23.60	32.30	42.00	53.20
湿沥青和混凝土路面	0.3 ~ 0.4	0.97	3.95	8.85	15.70	24.60	35.50	48.20	63.00	79.70
冰雪路面	0.2 ~ 0.3	1.95	7.9	17.75	31.50	49.20	71.00	96.50	126.00	150.00

Initial speed of the car: 108 km/h = 30 m/s

Reaction time: $t_1 + t'_2 \sim 1$s; distance 30 m

Deceleration (减速): $a = \mu g = -3$ m/s

$$t''_2 + t_3 = \frac{v_0 - 0}{a} = \frac{30 - 0}{3} = 10\ s$$

$$\text{distance} = \frac{v_0^2 - 0}{2a} = \frac{30^2 - 0}{2 \times 3} = 150\ m$$

Total distance: 150 + 30 = 180 m

Homework 1: 1.1-1.5

1.1 The position of an object moving along an x axis is given by $x = 3t - 4t^2 + t^3$, where x is in meters and t in seconds. Find the position of the object at the following values of t: (a) 1 s, (b) 2 s, (c) 3 s, and (d) 4 s. (e) What is the object's displacement between t = 0 and t = 4 s? (f) What is its average velocity for the time interval from t = 2 s to t = 4 s? (g) Graph x versus t for $0 \leq t \leq 4$ s and indicate how the answer for (f) can be found on the graph.

1.2 An electron moving along the x axis has a position given by $x = 16te^{-t}$ m, where t is in seconds. How far is the electron from the origin when it momentarily stops?

1.3 The position function x(t) of a particle moving along an x axis is $x = 4.0 - 6.0t^2$, with x in meters and t in seconds. (a) At what time and (b) where does the particle (momentarily) stop? At what (c) negative time and (d) positive time does the particle pass through the origin? (e) Graph x versus t for the range -5 s to +5s. (f) To shift the curve rightward on the graph, should we include the term +20t or the term -20t in x(t)? (g) Does that inclusion increase or decrease the value of x at which the particle momentarily stops?

1.4 The position of a particle moving along an x axis is given by $x = 12t^2 - 2t^3$, where x is in meters and t is in seconds. Determine (a) the position, (b) the velocity, and (c) the acceleration of the particle at t = 3.0 s. (d) What is the maximum positive coordinate reached by the particle and (e) at what time is it reached? (f) What is the maximum positive velocity reached by the particle and (g) at what time is it reached? (h) What is the acceleration of the particle at the instant the particle is not moving (other than at t = 0)? (i) Determine the average velocity of the particle between t = 0 and t = 3s.

1.5 A car moves along an x axis through a distance of 900 m, starting at rest (at x = 0) and ending at rest (at x = 900 m). Through the first of that distance, its acceleration is +2.25 m/s^2. Through the rest of that distance, its acceleration is -0.750 m/s^2. What are (a) its travel time through the 900 m and (b) its maximum speed? (c) Graph position x, velocity v, and acceleration *a* versus time t for the trip.